

Constructing an EA-level Database for the Census

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Overview

❑ Stages in the Geographic Database Development

- Sources of geographic information
- Data conversion
- Data integration

❑ Implementation of the Database

- Data Modelling
- Relational Data Model
- Example

❑ Conclusion



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Stages in the geographic database development

❑ Geographic data sources for EA delineation

- Inventory of existing data sources
- Additional geographic data collection

❑ Geographic data conversion

- Digitizing/Scanning + raster-to-vector conversion
- Editing Geographic features
- Constructing and maintaining topology for geographic features

❑ Data integration

- Geo-referencing/Coding
- Combining and integrating/Additional delineation of EA boundaries

❑ Parallel activity

- Develop geographic attribute database
- Metadata development



Sources of geographic information

Identify existing
data sources

Additional geographic
data collection

Paper maps,
existing printed
air photos and
satellite imagery

Field mapping
products
such as
sketch maps

Digital air photos
and satellite
images

GPS coordinate
collection

Existing digital
maps



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Inventory of existing sources

- ❑ Institutions to be contacted for contribution of hard copy or digital maps:
 - National mapping agency (often the lead agency in the country);
 - Military mapping services;
 - Province, district and municipal governments. (transportation, social services, utility services and planning relevant information);
 - Various government/private organizations dealing with spatial data;
 - Geological or hydrological survey, Environmental protection authority, Utility and communication sector companies;
 - Donor activities
- ❑ All maps should be well documented/organized according to the organization of the census mapping programme (i.e, by census region or district)



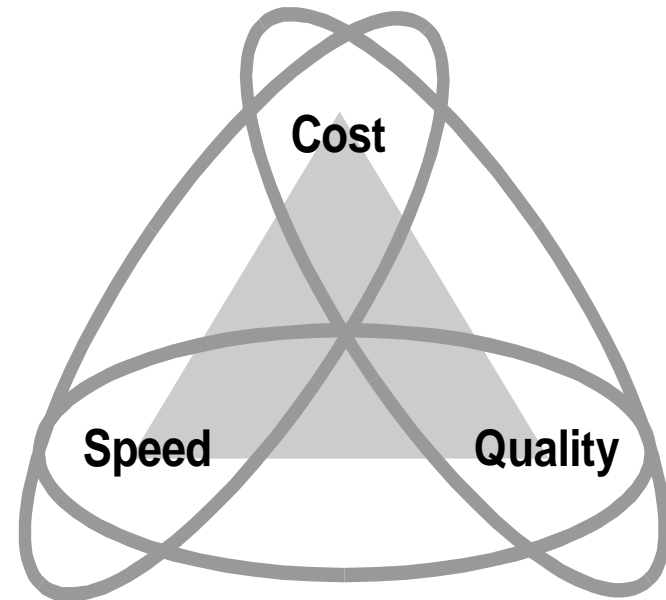
Why Data Inventory?

- ❑ Geographic data: Labor intensive, tedious and error-prone
- ❑ Up to 70% of GIS projects
- ❑ Identify existing data sources
 - Inventory, before proceeding to collection

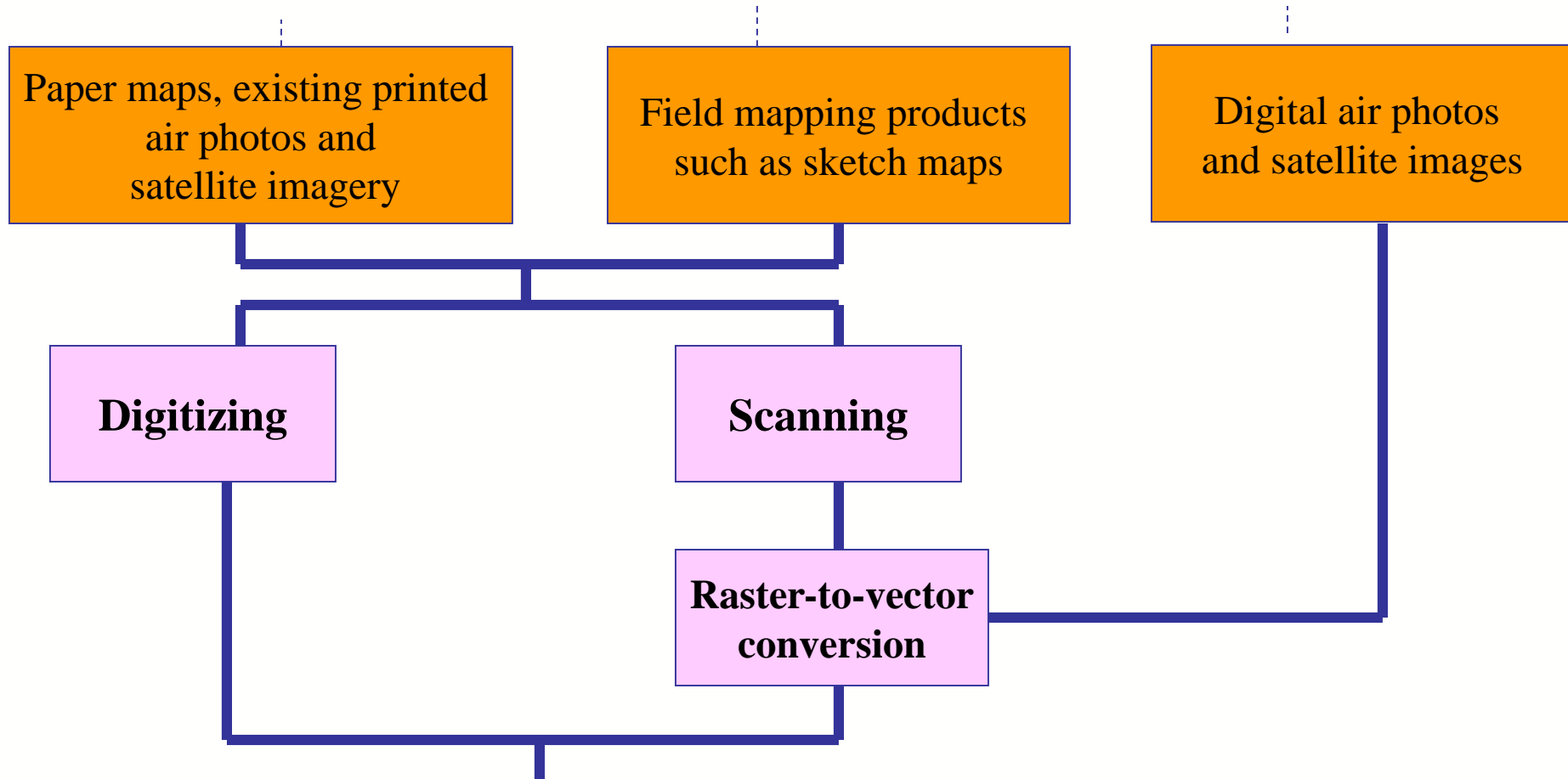


Geographic data conversion

- ❑ Need to have the multi-source data collected, in multiple format, available in digital format: Data Conversion
- ❑ **Data Conversion:**
 - The process of converting features that are visible on a hardcopy map into digital point, line, polygon and attribute information is called data automation or **data conversion**.
- ❑ The best strategy for data conversion depends on many factors including data availability, time and resource constraints
- ❑ Trade-off between the cost of a project, the amount of time required to complete data conversion, and the quality of the final product.



Data Conversion



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Geographic data conversion

❑ 2 main approaches for converting information on hardcopy maps to digital data:

- Scanning
- Digitizing



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Scanning

- ❑ Scanning has arguably bypassed digitizing as the main method of spatial data input, mainly because of the potential to automate some tedious data-input steps using large-format feed scanners and interactive “vectorization” software.
- ❑ The result of the scanning process is a **raster image** of the original map which can be stored in a standard image format such as GIF or TIFF.
- ❑ After geo-referencing it can be displayed in GIS packages as a backdrop to existing vector data.



Advantages and Disadvantages of Scanning

Advantages

- Scanned maps can be used as image backdrops for vector information;
- Clear base maps or original color separations can be “vectorized” relatively easily using raster-to-vector conversion software; and
- Small-format scanners are relatively inexpensive and provide quick data capture.

Disadvantages

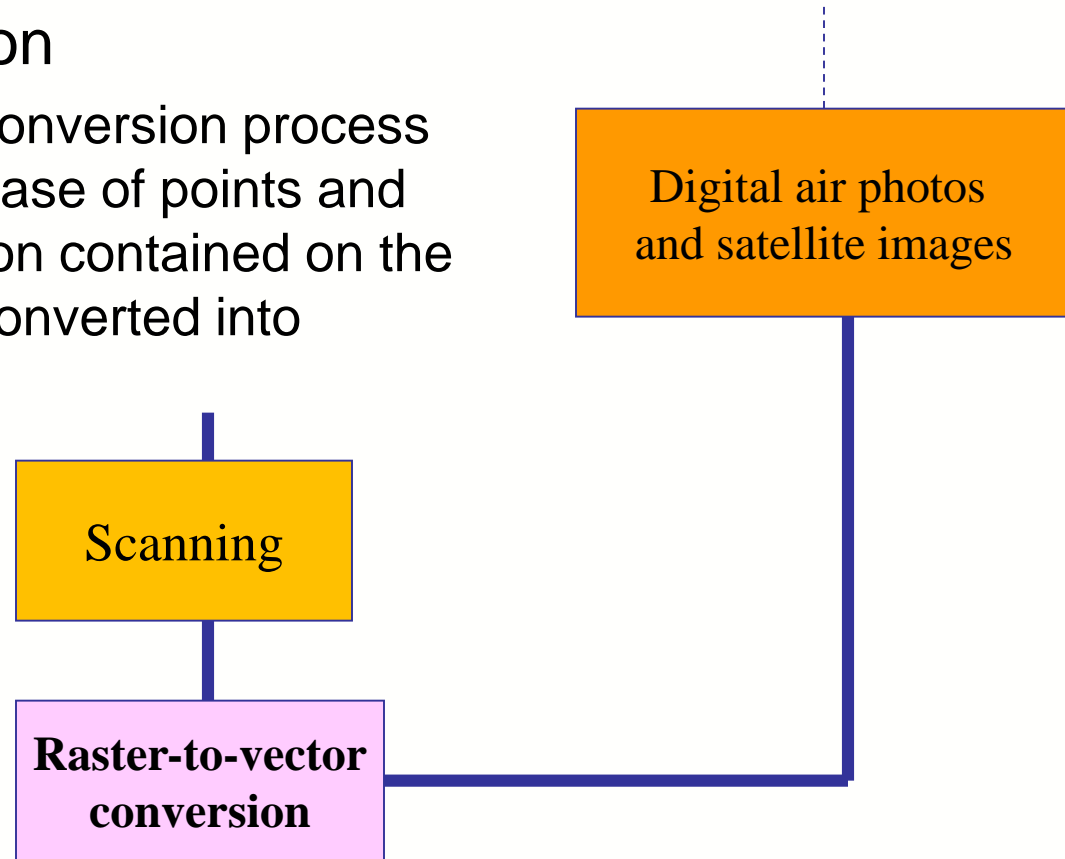
- Converting large maps with small format scanners requires tedious re-assembly of the individual parts;
- Scanning large volumes of hard-copy maps will present challenges for file storage on many desktop computer systems;
- Despite recent advances in “vectorization” software, considerable manual editing and attribute labeling may still be required.



Raster to Vector Conversion

❑ Raster to Vector Conversion

- Since the end result of the conversion process is a digital geographic database of points and lines, the scanned information contained on the raster images needs to be converted into coordinate information.



Digitizing

☐ Manual Digitizing

- Using digitizing tablet/table
- Digitizing is often tedious and tiring to the operators

☐ Heads up Digitizing

- In the heads-up digitizing, a scanned map image is used digitally to trace the outlines into a GIS layer



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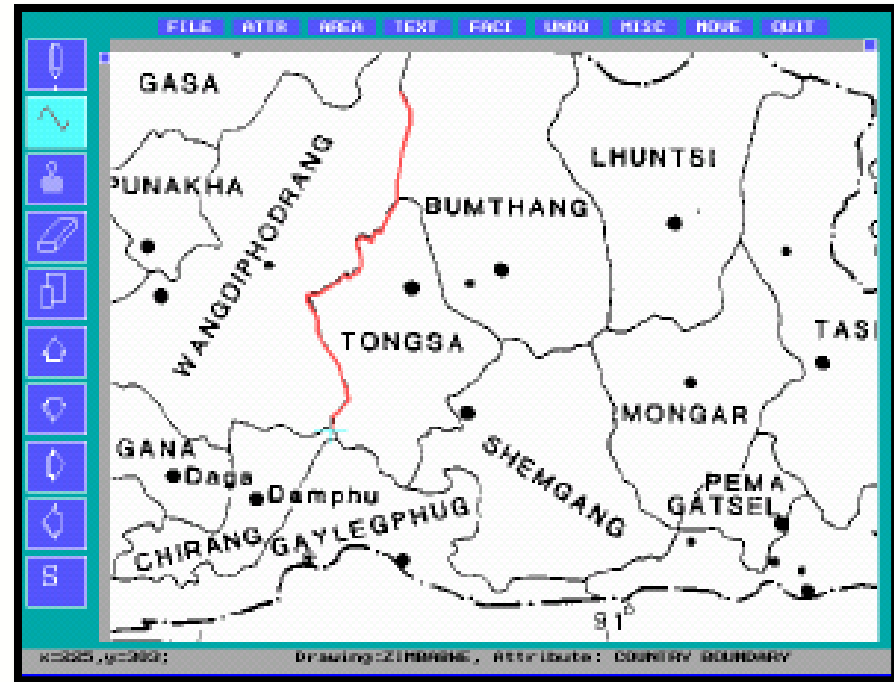
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Heads-Up Digitizing II

- Operator uses a Raster-scanned image on the computer screen (a scanned map, air photo or satellite image) as a backdrop.
- Operator follows lines on-screen in vector mode



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Advantages and Disadvantages of Digitizing

Advantages

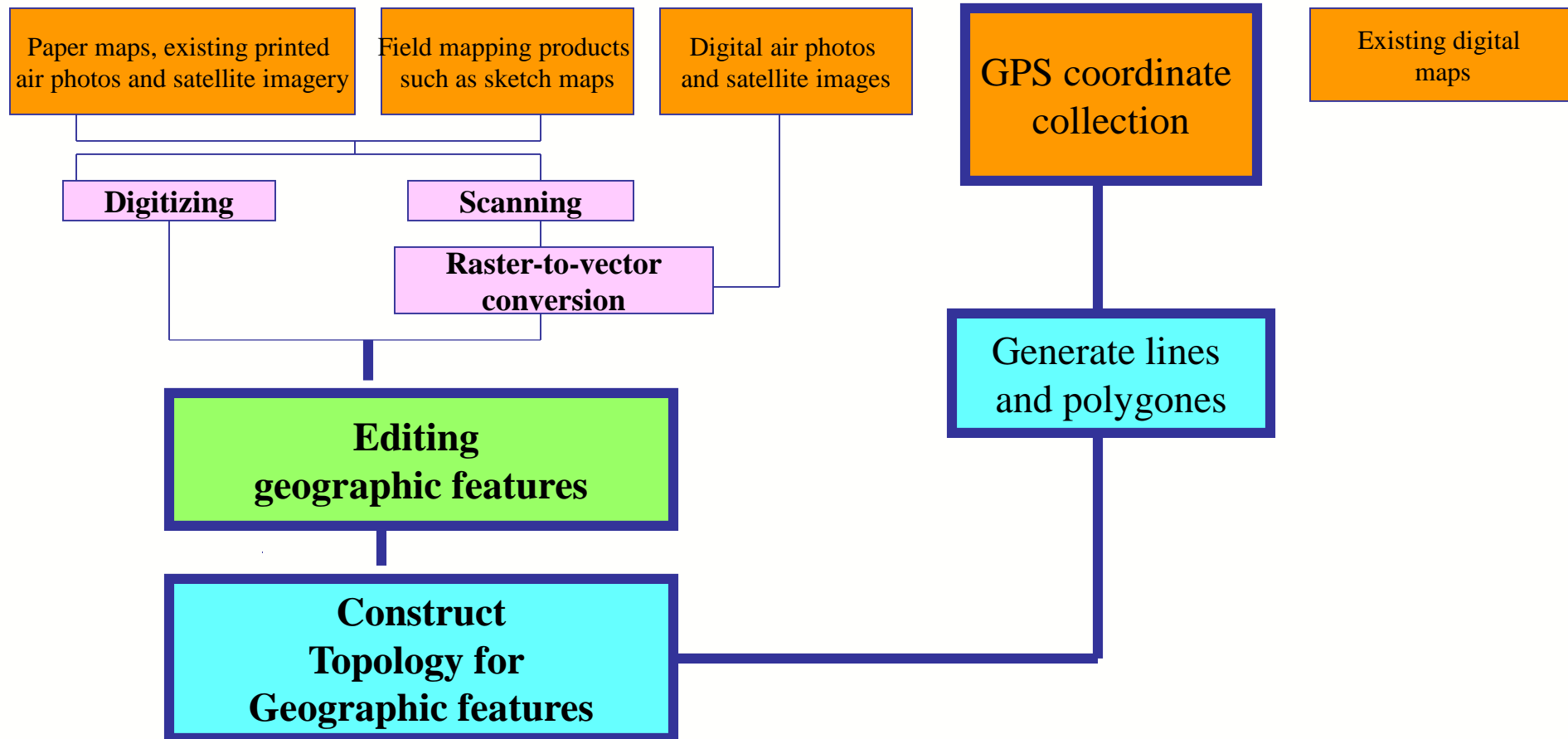
- Digitizing is easy to learn and thus does not require expensive skilled labor;
- Attribute information can be added during the digitizing process;
- High accuracy can be achieved through manual digitizing; i.e., there is usually no loss of accuracy compared to the source map.

Disadvantages

- Digitizing is tedious possibly leading to operator fatigue and resulting quality problems which may require considerable post-processing;
- Manual digitizing is quite slow;
- In contrast to primary data collection using GPS or aerial photography, the accuracy of digitized maps is limited by the quality of the source material.



Editing and Building topology



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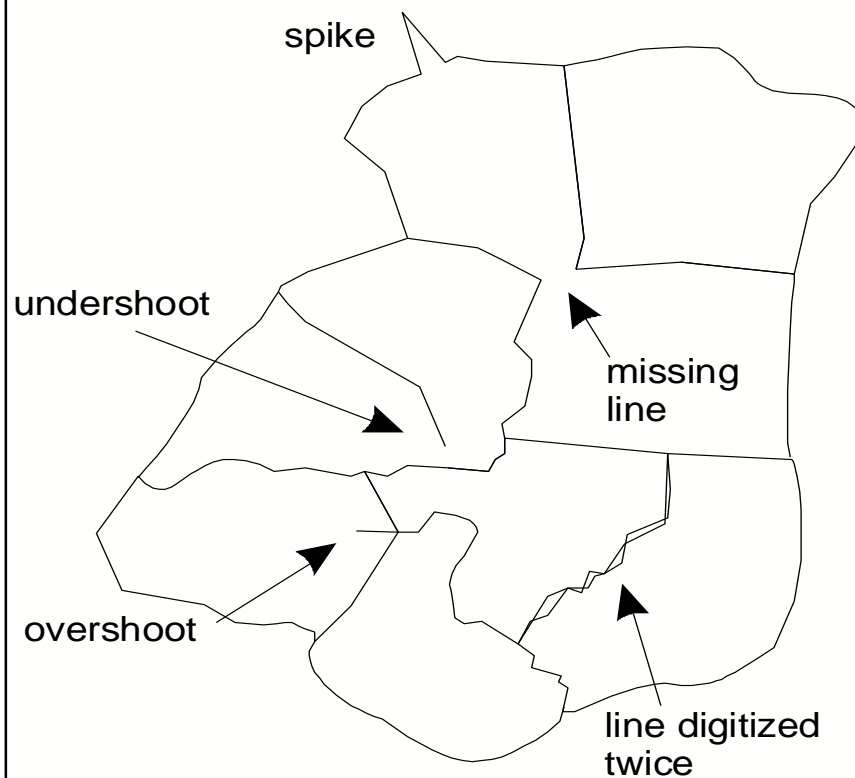
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Editing

- Manual digitizing is error prone
- Objective is to produce an accurate representation of the original map data
- This means that all lines that connect on the map must also connect in the digital database
- There should be no missing features and no duplicate lines
- The most common types of **errors**
 - Reconnect disconnected line segments, etc.



Some common digitizing errors



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Fixing Errors

- Some of the common digitizing errors shown in the figure can be avoided by using the digitizing software's snap tolerances that are defined by the user.
- For example, the user might specify that all endpoints of a line that are closer than 1 mm from another line will automatically be connected (snapped) to that line.
- Small sliver polygons that are created when a line is digitized twice can also be automatically removed.



Topology



Data structure in which each point, line and polygon :

- “knows” where it is
- “knows” what is around it
- “understands” its environment
- “knows” how to get around

Helps answer the question what is where?



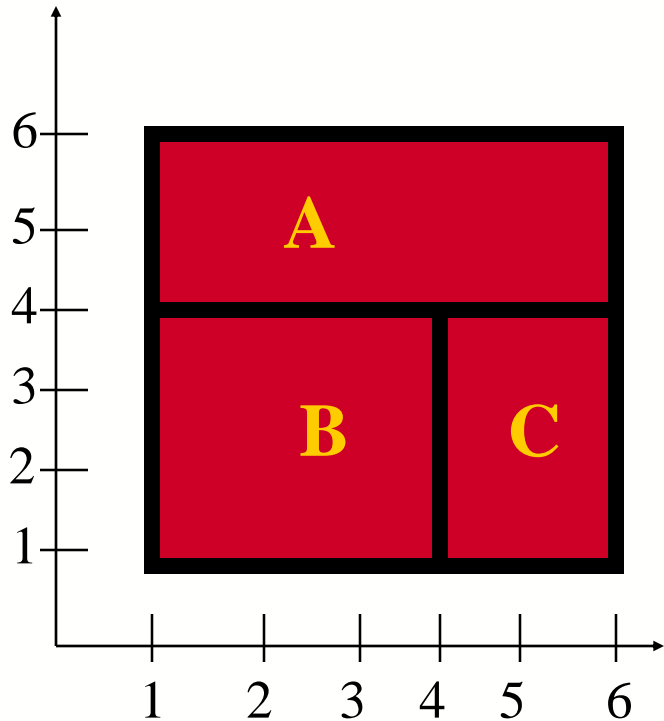
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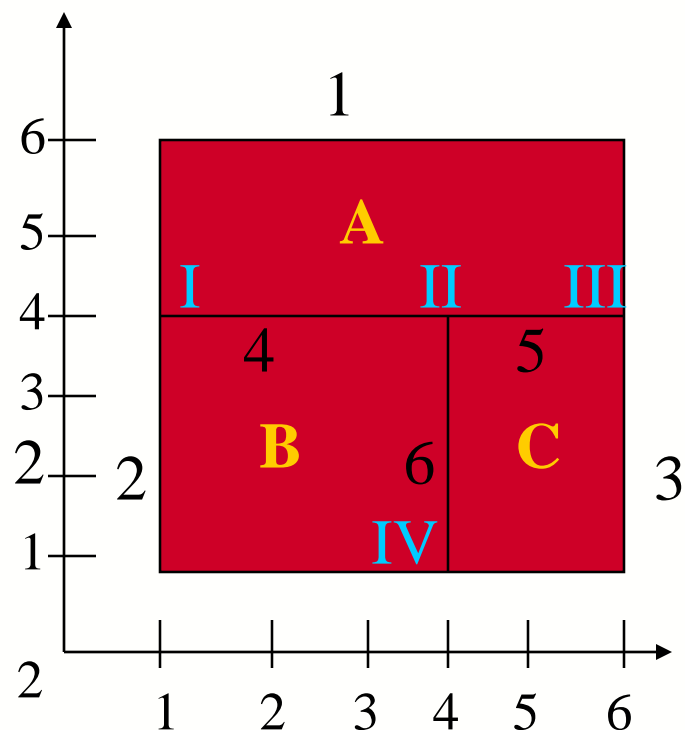
Example of “Spaghetti” data structure



| Poly | coordinates |
|------|--|
| A | (1,4), (1,6), (6,6), (6,4), (4,4), (1,4) |
| B | (1,4), (4,4), (4,1), (1,1), (1,4) |
| C | (4,4), (6,4), (6,1), (4,1), (4,4) |



Example of Topological data structure



O = “outside” polygon

| Node | X | Y | Lines |
|------|---|---|-------|
| I | 1 | 4 | 1,2,4 |
| II | 4 | 4 | 4,5,6 |
| III | 6 | 4 | 1,3,5 |
| IV | 4 | 1 | 2,3,6 |

| Poly | Lines |
|------|-------|
| A | 1,4,5 |
| B | 2,4,6 |
| C | 3,5,6 |

| | From | To | Left | Right |
|------|------|------|------|-------|
| Line | Node | Node | Poly | Poly |
| 1 | I | III | O | A |
| 2 | I | IV | B | O |
| 3 | III | IV | O | C |
| 4 | I | II | A | B |
| 5 | II | III | A | C |
| 6 | II | IV | C | B |



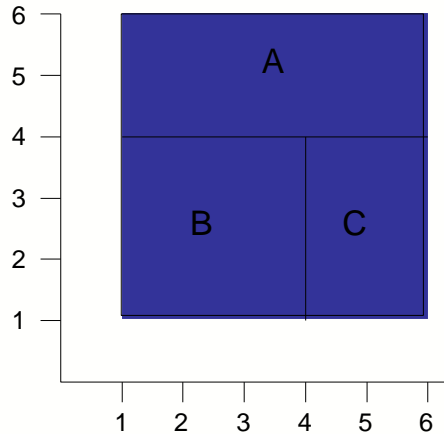
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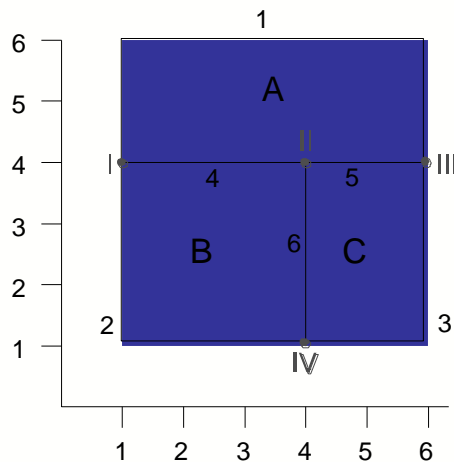
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“Spaghetti” data structure



| Poly | Coordinates |
|------|--|
| A | (1,4), (1,6), (6,6), (6,4), (4,4), (1,4) |
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Topological data structure



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| Poly | Lines |
|------|-------|
| A | 1,4,5 |
| B | 2,4,6 |
| C | 3,5,6 |

| Line | From Node | To Node | Left Poly | Right Poly |
|------|-----------|---------|-----------|------------|
| 1 | I | III | O | A |
| 2 | I | IV | B | O |
| 3 | III | IV | O | C |
| 4 | I | II | A | B |
| 5 | II | III | A | C |
| 6 | II | IV | C | B |



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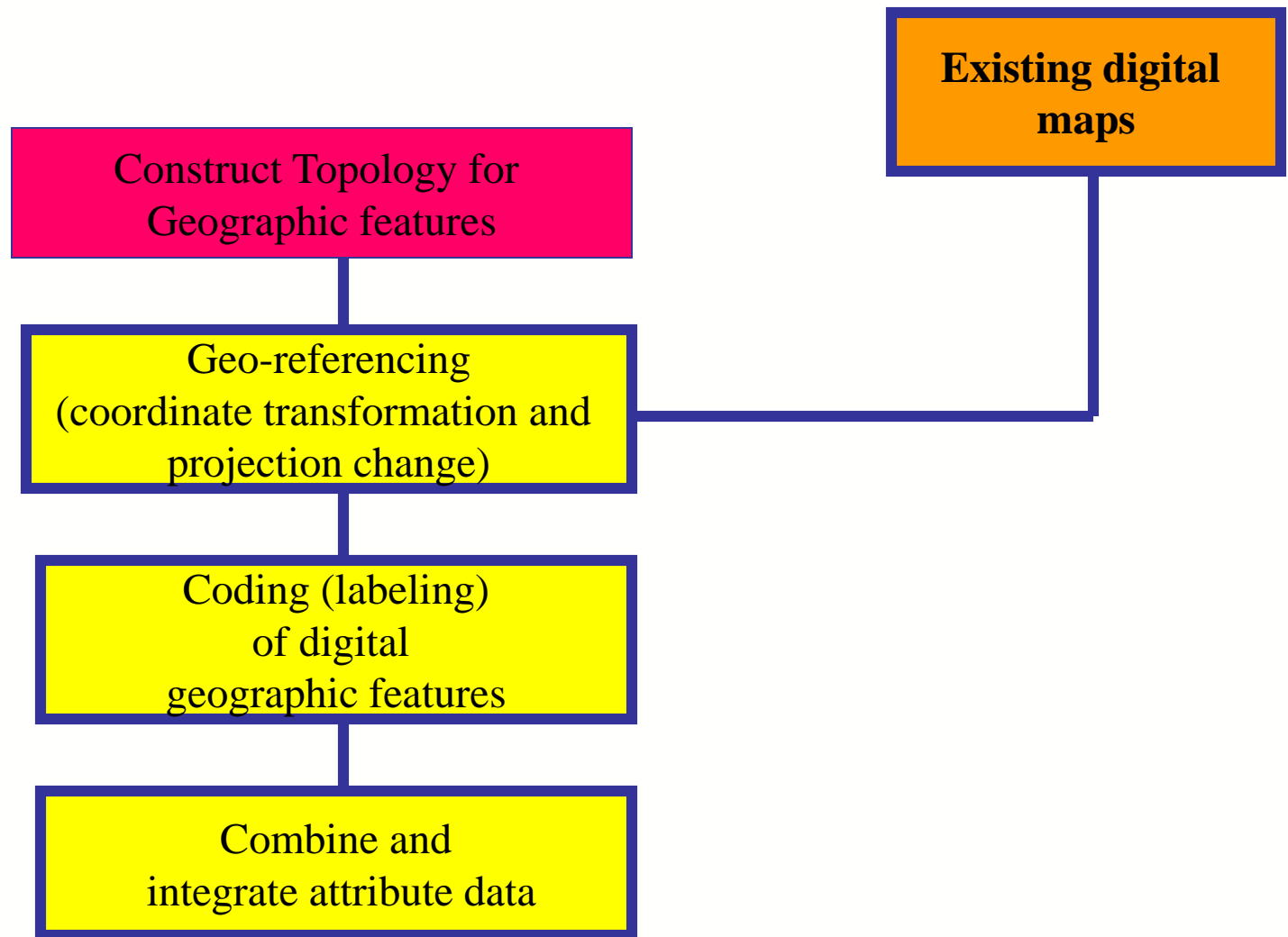
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Constructing and maintaining topology (cont.)

- Storing the topological information facilitates analysis, since many GIS operations do not actually require coordinate information, but are based only on topology
- The user typically does not have to worry about how the GIS stores topological information. How this is actually done is software-specific.
- Building topology thus also acts as a test of database integrity



Digital data integration



Integrating data

❑ Geo-referencing

- Converting map coordinates to the **real world coordinates** corresponding to the source map's cartographic projection (or at digitizing stage).
- Attaching codes to the digitized features

❑ Integrating attribute data

- Spreadsheets
- links to external database



Integrating attribute data

- After the completed digital database has been verified to be error-free, the final step is to add additional attributes
- These can be linked to the database permanently, or the additional information about each database feature can be stored in separate files which are linked to the geographic database as needed



Implementation of an EA database

- Geographic databases (hereafter referred to as geodatabases) are more than spreadsheets
- Entity types can be defined as having specific properties that govern behavior in the real world.
- The EA as a geographic unit is a kind of object whose function is to delineate territory for the census canvassing operation.
- Morphologically, the EA is contiguous, it nests within administrative units, and it is composed of population-based units.



Implementation of an EA database (cont.)

- All large operational GISs are built on geodatabases;
- Arguably the most important part of the GIS
- Geodatabases form the basis for all queries, analysis, and decision-making.
- A DBMS, or database management system, is where databases are stored.



Levels of Data Abstraction

Human-oriented

Reality

Conceptual Model

(user's perception of the real world)

Logical Model

(a formal description of the data model)

Physical Model

(physical storage of the data
e.g., format, order, path)

Increasing
Abstraction

Computer-oriented



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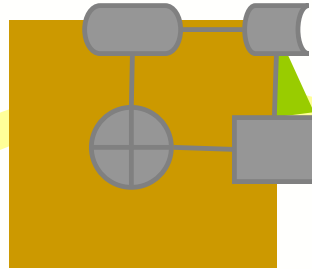
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Levels of Data Abstraction

Conceptual Model

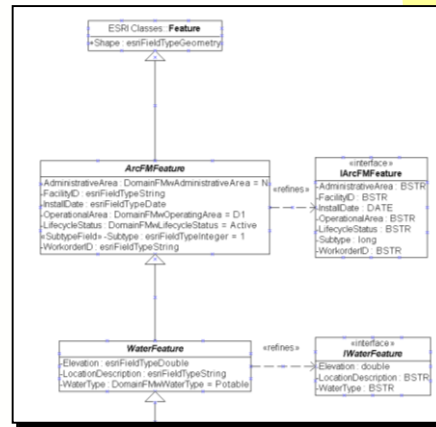
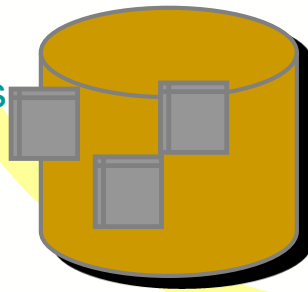
- software and hardware independent
- describes and defines included entities
- identifies how entities will be represented in the database: i.e. selection of spatial objects - points, lines, polygons, raster cells
- requires decisions about how real-world dimensionality and relationships will be represented:
 - based on the processing that will be done on these objects
 - e.g. should a building be represented as an area or a point?

Real World



Physical Model

- both hardware and software specific
- how files will be structured for access from the disk - Database Schema



Logical Model

- software specific but hardware independent
- sets out the logical structure of the database elements, determined by the database management system used by the software



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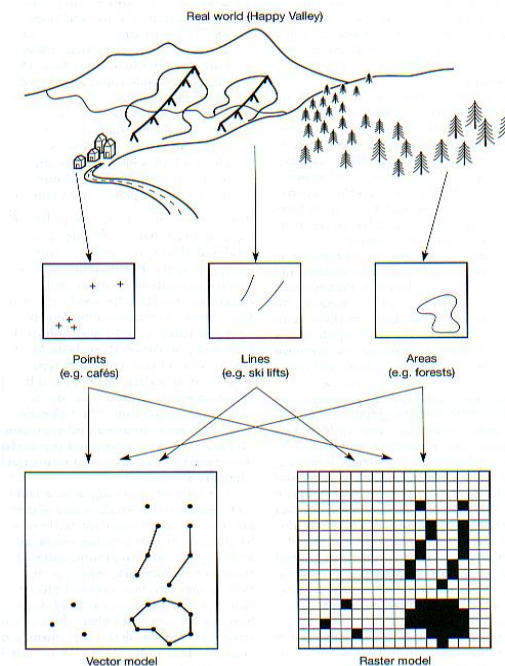
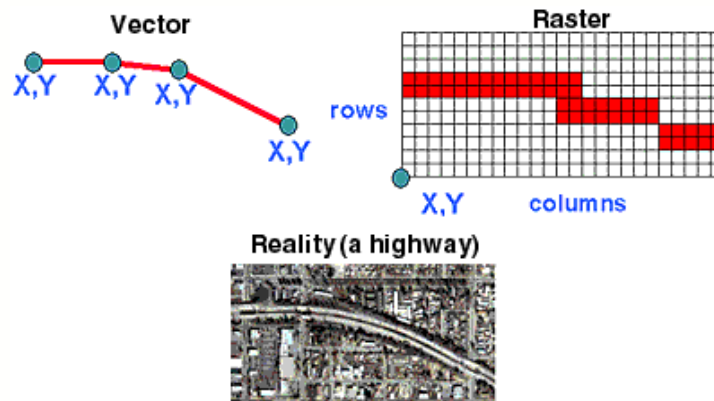
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GIS Data Models

- Vector data model
- Raster data model



courtesy: Mary Ruvane, <http://ils.unc.edu/>



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Several types of data organization

- ❑ Database management systems (DBMSs) can be divided into various types, including:
 - Relational
 - Object
 - Object-relational
- ❑ Relational (RDBMS)
 - RDMS is the most popular type of DBMS
 - Over 95% of data in DBMS is in RDBMS
 - DB2; SQL Server, Access; Oracle; Informix



Example: the Relational Database Model

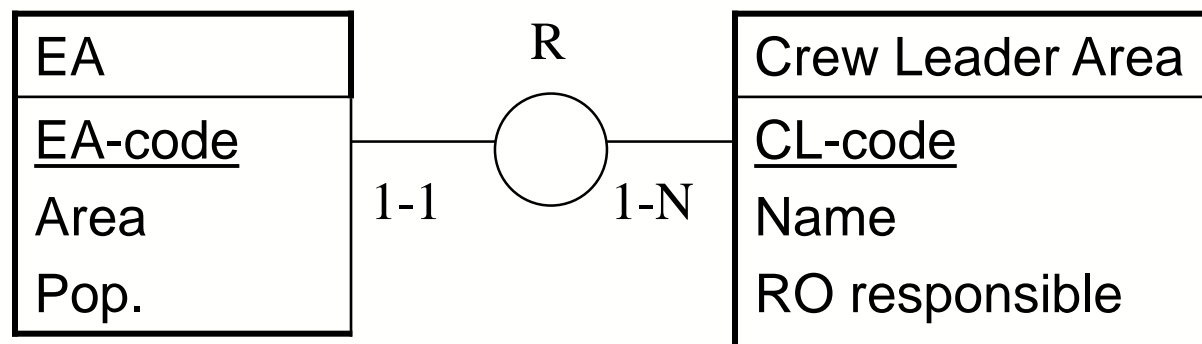
- The relational database model is used to store, retrieve and manipulate tables of data that refer to the geographic features in the coordinate database.
- It is based on the **entity-relationship** model
- In a geographic context, an *entity* can be administrative or census units, or any other spatial feature for which characteristics will be compiled.



Entity-Relationship Example:

EA entity can be linked to the entity **Crew Leader Area**.

The table for this entity could have attributes such as the **name of the crew leader**, the **regional office responsible**, **contact information**, and the **crew leader code** (CL code) as **primary code**, which is also present in the EA entity.



Implementation of an EA database

- Example of an entity table
– enumeration area

Entity: Enumeration areas

Type (attributes)

| EA-Code | Area | Pop | CL-Code |
|---------|------|-----|---------|
| 723101 | 32.1 | 763 | 88 |
| 723102 | 28.4 | 593 | 88 |
| 723103 | 19.1 | 838 | 88 |
| 723201 | 34.6 | 832 | 88 |
| 723202 | 25.7 | 632 | 89 |
| 723203 | 28.3 | 839 | 89 |
| 723204 | 12.4 | 388 | 89 |
| ... | ... | ... | ... |

Instances

*Primary
key*



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Example of an urban EA map

Main components are:

Street network,
Buildings
EA boundaries layer
Annotation,
Symbols,
Labels
Building numbers
Neatlines
Legend



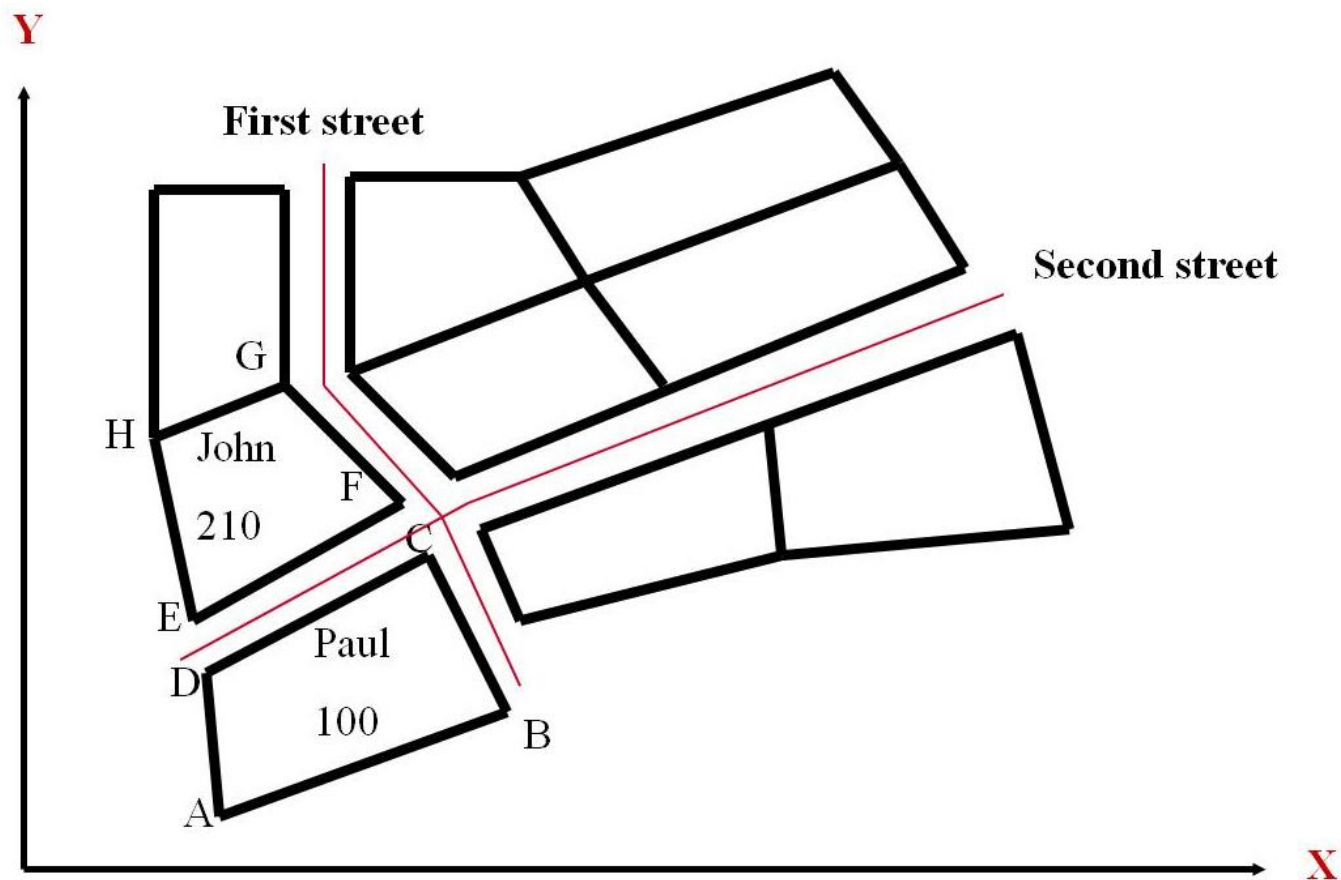
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An example of land parcels



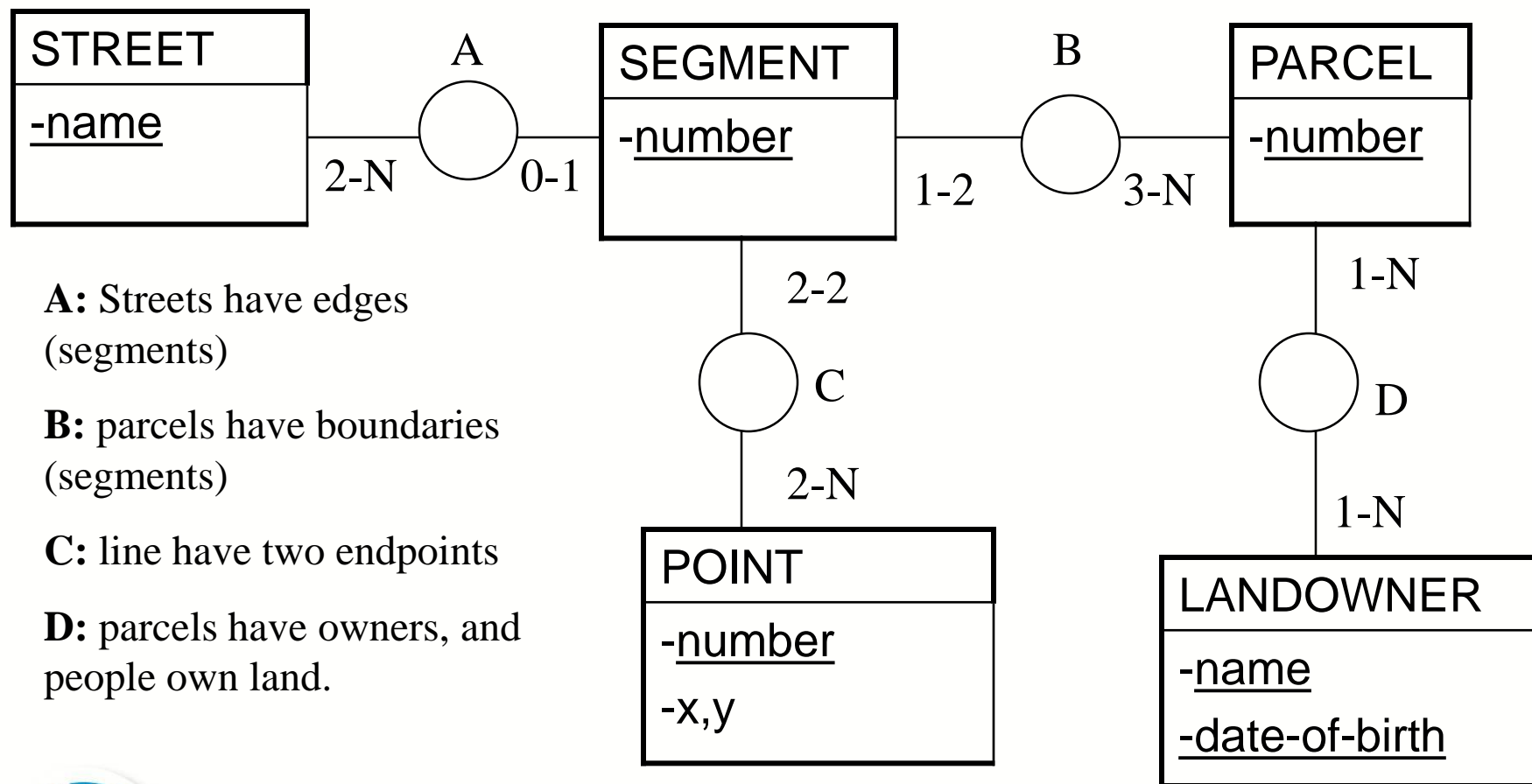
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The E/R diagram for land parcels



A: Streets have edges (segments)

B: parcels have boundaries (segments)

C: line have two endpoints

D: parcels have owners, and people own land.



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Data Tables

STREET

| Street-ID | Street_name |
|-----------|---------------|
| 101 | First street |
| 102 | Second Street |

STREET- SEGMENT

| Street-ID | Segment-ID |
|-----------|------------|
| 101 | g |
| 101 | h |
| ... | ... |
| 102 | i |
| 102 | j |
| ... | ... |

| Segment-ID | Point1-ID | Point2-ID |
|------------|-----------|-----------|
| a | A | B |
| b | B | C |
| c | C | D |
| ... | ... | ... |

POINT

| Point-ID | X | Y |
|----------|--------|-------|
| A | 101.11 | 70.12 |
| B | 100.67 | |
| 145.33 | | |
| ... | ... | ... |



Object-Oriented and Object-Relational GIS DBMS

- ❑ Object-oriented (OODBMS)
 - Based on OO concept to store state and behavior of GIS objects in databases
 - Provide OO query tools
 - Commercially not successful

- ❑ Object-Relational (ORDBMS)
 - Extend RDMS to handle GIS objects
 - Current Geographic Databases are ORDBMS



Data Dictionary

- Definition:

A data catalog that describes the contents of a database. Information is listed about each field in the attribute table and about the format, definitions and structures of the attribute tables. A data dictionary is an essential component of metadata information.



Spatial Analysis: Query

- ❑ Select features by their attributes:
 - “find all districts with literacy rates $< 60\%$ ”
- ❑ Select features by geographic relationships
 - “find all family planning clinics within this district”
- ❑ Combined attributes/geographic queries
 - “find all villages within 10km of a health facility that have high child mortality”

Query operations are based on the SQL (Structured Query Language) concept



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Spatial Analysis (cont.)

- **Buffer:** find all settlements that are more than 10km from a health clinic
- **Point-in-polygon operations:** identify for all villages into which vegetation zone they fall
- **Polygon overlay:** combine administrative records with health district data
- **Network operations:** find the shortest route from village to hospital
- Advanced spatial analysis – Multi-criteria Analysis



Summary

☐ Data conversion

- Digitizing/Scanning
- Editing
- Building Topology

☐ Data integration

- Geo-referencing; Projection change
- Coding
- Integration of attribute data

☐ Building EA Database

- Data Modelling: A spatial data model
- Database Implementation



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Thank You!



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Illustration

